NATIONAL BUREAU OF STANDARDS REPORT

5885

CAPACITY TESTS OF A MATHES HEAT PUMP
MODEL 27HAR-REB-HP

by

Joseph C. Davis
Paul R. Achenbach

Report to
Seymour Johnson Air Force Base
Goldsboro, North Carolina

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to
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ABSTRACT

At the request of the Contracting Officer, Seymour Johnson Air Force Base, cooling and heating capacity tests were made of a Mathes air-to-air heat pump, Model 27HAR-REB-HP. These tests were made at the indoor and outdoor conditions stated in the contract specifications, except that the air circulation rate and static pressure at the outlet of the indoor coil was set at 1100 cfm and 0.24 in. W.G. respectively in accordance with an agreement between the U. S. Air Force and the Mathes Company. These tests, except for minor deviations, were made under the procedures and conditions specified by the American Society of Refrigerating Engineers Standard No. 16-56. The observed cooling capacity was 23,700 Btu/hr at the specified test conditions whereas the minimum required was 27,000 Btu/hr. The observed heating capacity, without auxiliary strip heaters was 14,300 Btu/hr, whereas the minimum required was 22,800 Btu/hr. At rated voltage the strip heaters had a capacity of 3.2 KW as compared to the requirement of 3.6 KW. One modification was made in the indoor unit by the Mathes Company due to malfunctioning of a check valve. To improve heating performance the Company changed capillary tubes in the outdoor unit until they found one that gave the best performance.

1. INTRODUCTION

In accordance with a request from Captain W.A. Schrontz, Contracting Officer, Seymour Johnson Air Force Base, United States Air Force, by letter dated August 22, 1957, tests were made to determine the cooling and heating capacity of a Mathes Heat Pump, Model 27HAR-REB-HP. These tests represented the second phase of a series of tests on three models of heat pumps that will be used at this site. Results of tests of the first model are covered in National Bureau of Standards Report No. 5818, "Capacity Tests of Mathes Heat Pump Model 38HAR-LEB-HP."

Specifications supplied by Captain Schrontz, Section 27A-Heat Pumps (Alternate) of the contract specifications and drawings for homes under construction at Seymour Johnson Air Force Base, require a total heating capacity for the 27HAR-REB-HP of 27,000 Btu/hr and a total heating capacity of 35,086 Btu/hr. A breakdown of the capacity requirements for these two conditions follows:

COOLING CAPACITY (Btu/hr)

Sensible	Latent	Total
18,900	8,100	27,000

HEATING CAPACITY (Btu/hr)

Condenser Heat Transfer	From Auxiliary Strip Heater	Total
22,800	12,286	35,086

The specifications also require that the minimum air circulation rate be 1000 cfm against an external static resistance of 0.2 inch of water. However, by agreement between USAF and the Mathes Company before the tests began, both cooling and heating tests were performed at a minimum air circulation rate of 1100 cfm against an external static resistance of 0.24 inch of water. This change in the test conditions was confirmed in a letter from Captain W. A. Schrontz, dated April 3, 1958.

2. DESCRIPTION OF TEST SPECIMEN

The Model 27HAR-REB-HP, similar to the model previously tested, is known as a "split-type" unit in which one section is placed outdoors and the other inside the home at a suitable place for delivering conditioned air. The two sections involved will be designated hereinafter as the inside unit and the outdoor unit. The indoor unit, similar to that tested previously, is known as a horizontal unit because the chilled air is discharged in a horizontal direction from the unit.

During the cooling cycle, the coil of the indoor unit served as an evaporator, absorbing heat; and during the heating cycle, as a condenser, rejecting heat. This operational change was accomplished by means of a change in direction of circulation of the refrigerant through the system, using a thermostatically-controlled solenoid in a four-way valve. During the test the solenoid was controlled by a manually operated switch to preclude shifting from cooling to heating or vice versa. Capillary tubes were used as the liquid refrigerant flow control device in both the indoor and outdoor units with check-valves to by-pass each when not needed. Following the new ASRE refrigerant designations, the refrigerant was R-22.

The indoor unit, except for the capillary tube, is the same as that for the 38 HAR-LEB. It consisted of a coil (used as an evaporator during cooling), a blower for circulating conditioned air through the duct system of the home, and a capillary tube-check valve assembly. The coil was a three-row coil, 30 in. wide and 20 in. high, with 13 fins per in. of tube length. A Torrington blower with a 13-in. diameter wheel was used and it was powered by a 1/3 HP single phase motor. Nameplate rating of the motor was 230 volts, 2.7 amperes, with a service factor of 1.35. A speed of rotation of 1725 rpm was also specified on the nameplate and measurements after testing showed an rpm of 1660. The capillary tube had an ID of 0.1005 in. and a length of 60.2 in. The housing of the indoor unit was 34.3 in. wide, 33.2 in. deep, and 28.5 in. high. Wall thickness 0.053 in.

With the indoor motor pulley adjusted after the test for 1100 cfm air delivery on cooling, and with the temperature at about 75°F, the fan speed of rotation was 705 rpm.

The outdoor unit consisted essentially of a coil (used as an evaporator during heating); a propeller fan; a hermetically- sealed Tecumseh No. H200TA-2-A1566 motor compressor, 230 volts, 60 cycles, single phase, full load amperage 9.3; a capillary tube-check valve assembly; and a four-way valve. The coil had 2 rows, was 46 in. wide and 28 in. high, and had 13 fins per in. of tube length. The fan blade assembly, 24 in. in diameter with a 40° pitch for each blade, was powered by a 1/3 HP motor, single phase, 2.7 amperes, with a service factor of 1.36, and with a rotational speed of 1725 rpm. The capillary tube had an ID of 0.0745 in. and a length of 84 in. The housing of the outdoor unit was 51 in. wide, 27 in. deep, and 31 in. high. Wall thickness was 0.061 in. The 38 HAR-HP outdoor unit, which is the same as the 27 HAR-REB-HP except for the compressor and capillary tube-check valve assembly, is shown in figure 2 with grilled panel removed.

Measurements of the outdoor fan speed at an outdoor temperature of about 75°F showed 835 rpm.

Figure 3 shows the opposite side of the outdoor unit facing the coil. Note the five-in-one thermocouple system and the thermostat used for controlling outdoor conditions during the test.

A schematic diagram of the heat pump system and auxiliary equipment is shown in figure.1.

A list of line sizes for this system and its auxiliary equipment is shown below:

		Size OD in.
1.	Discharge line from outside of unit to oil separator	1/2
2.	Oil separator to 4-way valve	1/2
3.	Oil return lines	1/4
4.	Compressor suction to 4-way valve	5/8
5.	Four-way valve to coil of outdoor unit	5/8
6.	Liquid line to flowmeter manifold	3/8
7.	Lines in manifold	1/2
8.	Vapor line	3/4

Some modifications of the heat pump were made by the manufacturer during the test to improve its performance. These modifications are described in a later section of the report.

3. METHODS OF TESTING

Except for minor deviations, the heat pump was tested under the conditions described in ASRE Testing and Rating Standard No. 16-56, as required by the specification. Figure 4 shows the enclosure housing the indoor unit and the 33-in. square test duct attached to the outlet side of the unit. This duct housed the nozzle used for measuring air circulation rate and the instruments for measuring temperature and humidity of the outlet air. Because the nozzle, mixing baffles, and screen introduced considerable resistance in the outlet duct, an auxiliary blower powered by a one-HP motor was provided at the downstream end of the 33-in. duct. By adjustment of a wooden slide-type damper at the outlet of the auxiliary blower, the static resistance imposed upon the indoor unit blower was adjusted to 0.24 inch of water. The auxiliary blower, return air heaters, and humidifier are shown in figure 5.

ASRE Standard 16-56 requires that two independent measuring methods be used during the test, each as a check on the other. One method, known as the psychrometric method, involved measuring the mass-flow of air through the indoor unit and the change in enthalpy of the air across the unit. The other method involved determination of the flow of refrigerant through the indoor coil and the change in enthalpy of the refrigerant across the indoor coil. A correction to the total enthalpy change of the refrigerant is necessary, either by adding or subtracting the heat equivalent of the electrical energy supplied to the indoor blower motor depending on whether the heating or cooling cycle is in use before comparing it with the result of the psychrometric method. Values obtained by the two methods must not differ by more than six percent in order for a test to be valid.

Mass flow of air in the psychrometric method was obtained by measuring humidity and temperature conditions of the air entering the long-radius nozzle and the static pressure drop across the nozzle. Enthalpy change of the air was determined by measuring temperature, humidity, and barometric pressure of the air entering the indoor unit, and in the duct immediately after it left the unit.

In order to maintain 1100 cfm for both heating and cooling, it was necessary to set the speed of the indoor blower lower during heating than cooling. If the same blower speed pulley adjustment is used in the homes at Seymour Johnson Air Force Base, the flow of supply air will be slightly greater for heating than cooling. The pulley adjustment on the outdoor fan was the same for heating and cooling.

Flow of refrigerant was measured by means of a flowmeter in the liquid line of the system--a Potter Electronic type with an impeller which generated an electrical pulse on each revolution. A Potter counter coupled to the flowmeter served to translate the pulses into gal/unit time. By knowing temperature of the liquid in the line, the flow was converted to mass flow. Enthalpy change was determined by temperature and pressure measurements at the inlet and outlet of the indoor coil. For accurate measurement of capacity by the refrigerant flow method it was imperative that there be no gas bubbles in the liquid refrigerant as it passed through the meter, and that the liquid refrigerant all be evaporated in the coil.

To assure substantially oil-free refrigerant at the flowmeter, an oil separator was provided in the hot gas line between the compressor and four-way valve to separate the oil. The oil was returned to the refrigerant at the inlet to the indoor coil during the cooling cycle test and to the inlet of the coil in the outdoor unit during the heating cycle test.

During the test, power consumed by the indoor blower, outdoor fan, and compressor was read from separate watt-hour meters. Simultaneous readings were made of currents and voltages. The various meters, together with the other instruments for measuring temperature and humidity, are shown in figure 6.

The following "state" conditions for the indoor and outdoor air were maintained during the cooling cycle in accordance with contract specifications:

95°F DB outdoors
80°F DB inside
67°F WB inside (50 percent relative humidity)

Refrigerant charge was the same for the cooling test as for the heating test. The representatives of the Mathes Company elected to set this charge at optimum on the heating cycle such that on the cooling test following, there was some flooding at the outlet of the indoor unit. Steady state conditions were maintained for more than an hour before the test. During the test, readings were taken every ten minutes for two to three hours, and the hour representing the steadiest conditions was used for evaluating the performance of the unit.

For the heating test, the following "state" conditions for the indoor and outdoor air were maintained in accordance with the contract specifications:

20°F DB outdoors
70°F DB indoors

It was possible to maintain "state" conditions for both cooling and heating with the use of a test structure having two controlled temperatures.

To make certain that no refrigerant was lost between the heating test and the cooling test, immediately following the latter test, the temperature of the space representing the outdoors was lowered to 20°F and the more pertinent readings of the heating test observed. Values for head pressure, suction pressure, and temperature were essentially the same as during the heating test.

4. TEST RESULTS

A. Cooling Test

ASRE Standard 16-56 requires that values obtained by the psychrometric and flowmeter methods be averaged to obtain the rated capacity of the unit. Since the representatives of the Mathes Company chose to set the refrigerant charge so that there was some flooding at the outlet of the indoor unit during cooling operation, the flowmeter did not measure the amount of liquid evaporated in the indoor coil, so it would not have been proper to use the flowmeter data to obtain an average. However, ASRE 16-56 allows a maximum deviation of six percent between the two methods, and since the flowmeter method has usually given higher values on the cooling cycle than the psychrometric method, an increase of one half of this six percent, or three percent, was allowed.

Test results for the cooling test follow:

Summary of Cooling Capacity Values (Btu/hr)

	Test Value	Rounded Value
By psychrometric method	22,880	
Flowmeter allowance	690	
	23,570	
Correction for deviation of barometric pressure from standard barometric pressure	100	
	23,670	23,700

Following is a summary of the averages of the more significant data observed during the cooling test.

Psychrometric Method

Temperatures (°F)	
At inlet to enclosure around indoor unit	80.0 DB
At outlet of indoor unit in duct	63.6 DB
Temperature difference across indoor coil	16.4 DB
At inlet to outdoor unit	94.6 DB

Relative Humidities (%)	
At inlet to enclosure around indoor unit	49.8
At outlet of indoor unit in duct	83.7
Static Pressure across Nozzle (In. of H_2O)	1.12
Volume Air Flow at Nozzle (cfm)	1135
Mass Air Flow at Nozzle (lb dry air/hr)	5073
Barometric Pressure (In. of Hg)	29.73
Diameter of Nozzle (In.)	7.03
Nozzle Coefficient	.99
Static Resistance (In. of H_2O)	0.24
Pressures (psig)	
Compressor discharge	257.
In liquid line entering coil of indoor unit	241.
In vapor line leaving coil of indoor unit	84.

Difference in pressure across the oil separator was less than 2 psi.

Difference in pressure across the flowmeter was about 3 psi.

Other Temperatures (°F)

In liquid line entering coil of indoor unit	98.0
In vapor line leaving coil of indoor unit	50.8
In suction line of compressor	49.9

Motor Power Consumption (Watts)

Indoor blower	403
Outdoor fan	524
Compressor	2642
Total	3569

Coefficient of Performance	1.95

Motor Voltages (Volts)

Indoor blower	230.0
Outdoor fan	230.0
Compressor	230.0

Motor Currents (Amperes)

Indoor blower	2.74
Outdoor fan	3.10
Compressor	12.00

It will be noted that the compressor current was 12 amps, whereas the 9.3 amperes appeared on the nameplate as the full-load ampere rating.

B. Heating Test

The heating test, performed in accordance with the procedures described in ASRE Standard 16-56, except for minor deviations, gave the following results:

Summary of Heating Capacity Values (Btu/hr)

	Test Value	Rounded Values
By psychrometric method	14,300	
By flowmeter method	14,180	
Average	14,240	
Correction for deviation of barometric pressure during test from standard barometric pressure	50	
	14,290	14,300

Following is a summary of the averages of the more significant data observed during the heating test.

Psychrometric Method

Temperatures (°F)

At inlet to enclosure around indoor unit	69.7 DB
At outlet of indoor unit in duct	81.6 DB
Temperature difference across indoor coil	11.9 DB
At inlet to outdoor unit	19.6 DB

Relative Humidity of Indoor Air in Duct (%) 14.5

Static Pressure across Nozzle (In.of H_2O) 1.11

Volume Air Flow at Nozzle (cfm) 1140

Mass Air Flow at Nozzle (lb dry air/hr) 5006

Barometric Pressure (In. of Hg) 29.68

Diameter of Nozzle (In.) 7.03

Nozzle Coefficient .99

Static Resistance (In. of H_2O) .236

Flowmeter (Refrigerant Method)

Temperatures (°F)

In vapor line entering coil of indoor unit	94.2
In liquid line leaving coil of indoor unit	73.5

Pressures (psig)

In vapor line entering coil of indoor unit	182
In liquid line leaving coil of indoor unit	182

Potter Meter Count for 10 Minutes 477.8*

Other Pressures (psig)

Compressor discharge pressure	183.
Suction pressure	34.

Difference in pressure across the oil separator was less than 2 psi.

Difference in pressure across the flowmeter was about 5.5 psi. This difference caused less than 4 psi change in head pressure.

$$\text{*Refrigerant flow, gal/min} = \frac{\text{Meter Count for 10 min. x 100}}{18133.8}$$

Other Temperatures (°F)	
Compressor discharge	119.9
Suction line at compressor	9.0

Motor Power Consumption (Watts)

Indoor blower	385
Outdoor fan	684
Compressor	1677
Total	2746

Coefficient of Performance (Exclusive of strip heater) 1.52

Motor Voltages (Volts)

Indoor blower	229.9
Outdoor fan	230.6
Compressor	230.6

Motor Current (Amperes)

Indoor blower	2.67
Outdoor fan	3.73
Compressor	7.94

Power Consumption of Strip Heaters

Readings of the energy dissipated by the strip heaters in the indoor unit were made every ten minutes for a period of one hour with the following results:

Watthour meter value (Watts)	3211.0
Average terminal voltage (Volts)	227.8
Average current (Amperes)	13.94
Voltage times current (Watts)	3175.5

During the period in which the unit was being charged with refrigerant prior to the heating test, the oil separator was closed off from the rest of the system. The temperature around the outdoor unit was about 28°F. Then when

the separator was introduced into the system a decrease in head pressure of about 17 psi occurred. A part of this decrease was temporary, but the head pressure remained below the value observed when the oil separator was out of the system. By agreement enough refrigerant was added to raise the head pressure to its original value. All tests subsequent to this were performed with the oil separator in the system and with the added charge.

The oil separator, to limit length of lines exposed to the cold, was placed relatively close to the outdoor unit. In addition to the normal felt insulation furnished with the oil separator when purchased, it was insulated with a 1-in. layer of glass fiber and a 3/4-in. layer of hair felt; and the lines, except for a small section of each near the outdoor unit, were insulated with a sponge rubber type of material. With this insulation, it was expected that the separator would cause little heat loss in the vapor line to the indoor unit.

After the heating test, in order to determine the extent of the loss, a test was performed with the oil separator in the system, followed immediately by a period with the oil separator by-passed and with only vapor trapped in the separator. The data particularly noted during these comparative periods were change in head pressure, pressure at the inlet to the indoor coil in the vapor line, suction pressure, change in the count of the refrigerant flowmeter (due to oil in the refrigerant), change in the temperature rise of the air over the indoor coil, and change in temperature at vapor line entering coil of indoor unit. These data are presented below:

	With the separator	Without the separator
Head Pressure (psig)	181	185
Pressure at Inlet to Indoor Coil (psig)	177	181
Suction Pressure (psig)	35	34
Flowmeter Counter (counts per min.)	50.8	51.2
Temperature Rise of Air through the Indoor Coil (°F)	11.8	12.0
Temperature in Vapor Line Entering Indoor Coil (°F)	94.5	96.5

The small difference in temperature rise across the indoor coil indicates an increase in heat transfer of the coil of only about 250 Btu/hr without the separator. The increase in flowmeter indication was less than one percent, showing that little oil was being circulated with the refrigerant.

5. SYSTEM MODIFICATIONS

A. Replaced capillary tube-check valve assembly in the indoor unit because of malfunction.

B. Three capillary tube and check valve assemblies were tried in the outdoor unit while seeking to obtain an optimum capacity in the heating cycle. The dimensions of the three capillary tubes are listed below. The last of the three assemblies was used for the test reported in part B of section 4 of this report.

Initial	1st Change	2nd Change
0.0795 in., ID	0.0745 in., ID	0.0745 in. ID
59.375 in., Length	70.75 in., Length	84 in. Length

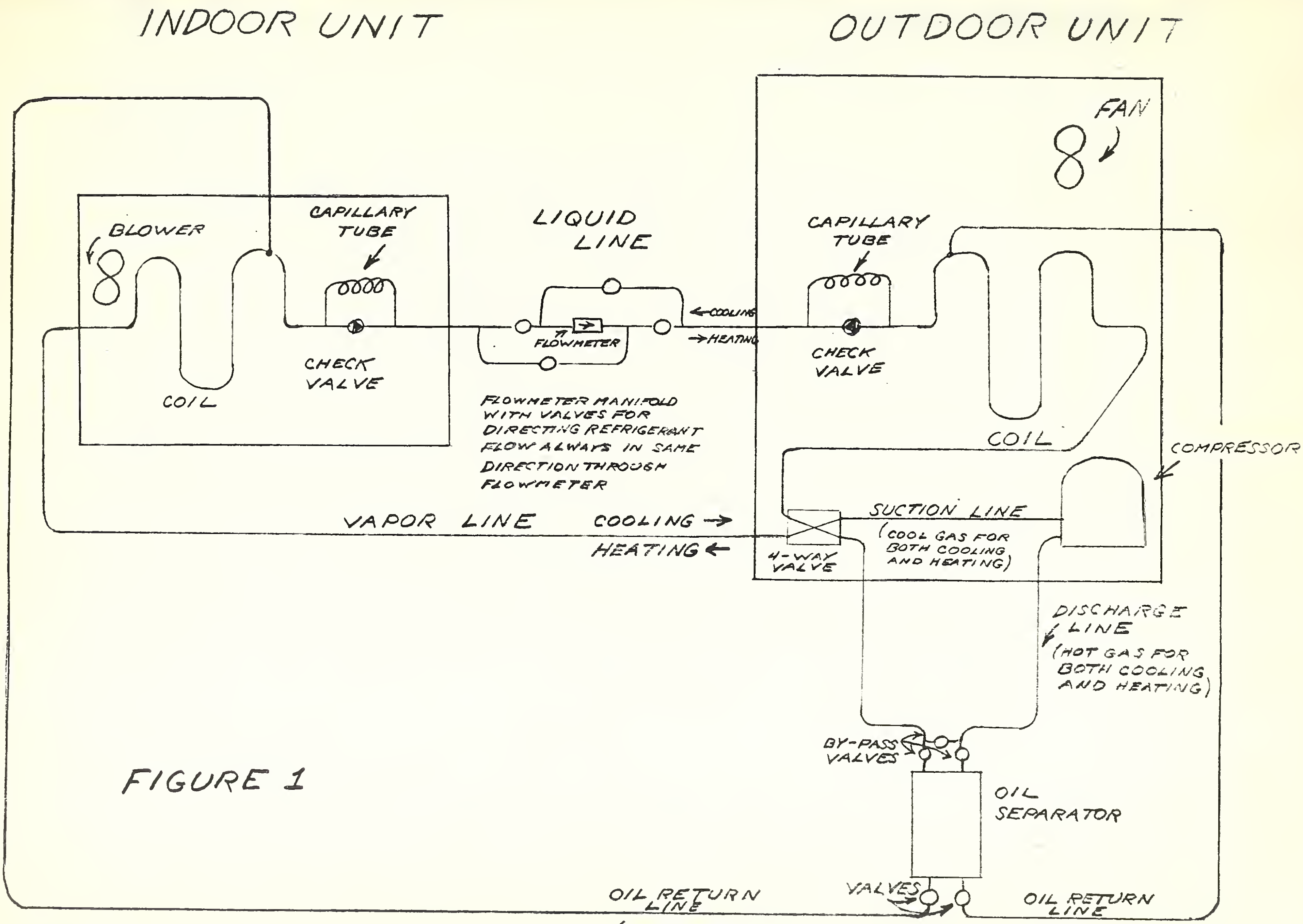

FIGURE 1

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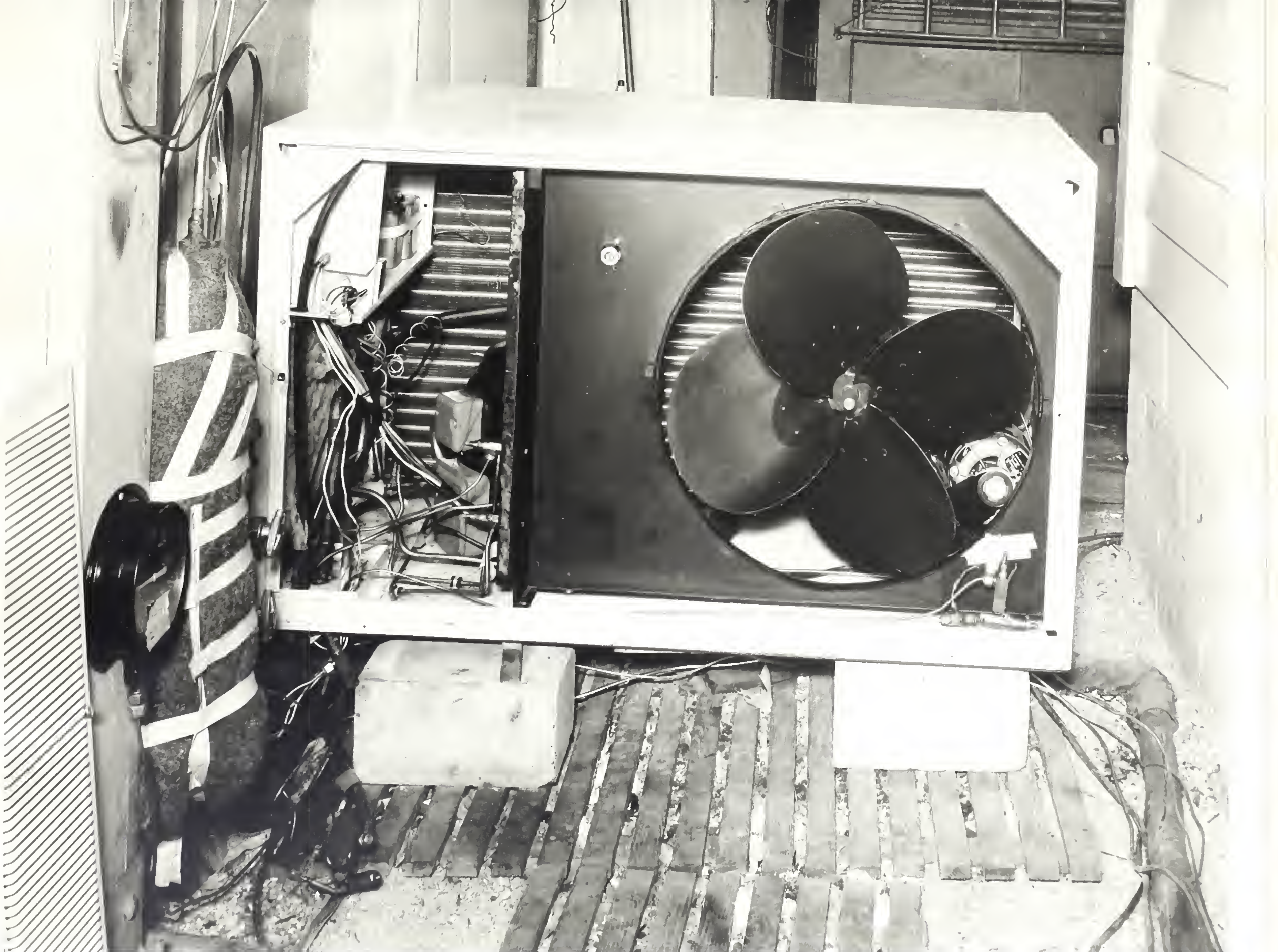

Figure 2

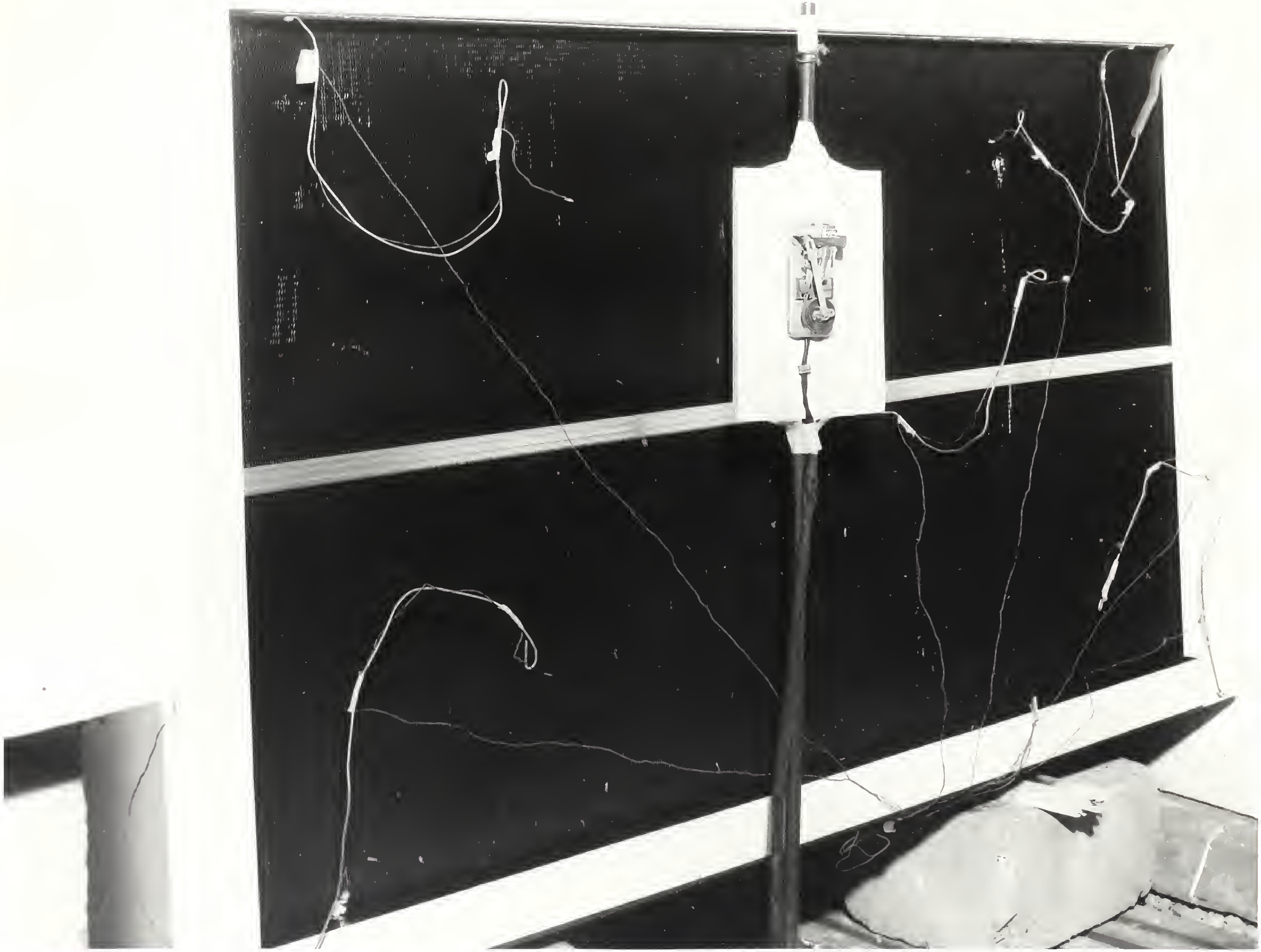

Figure 3

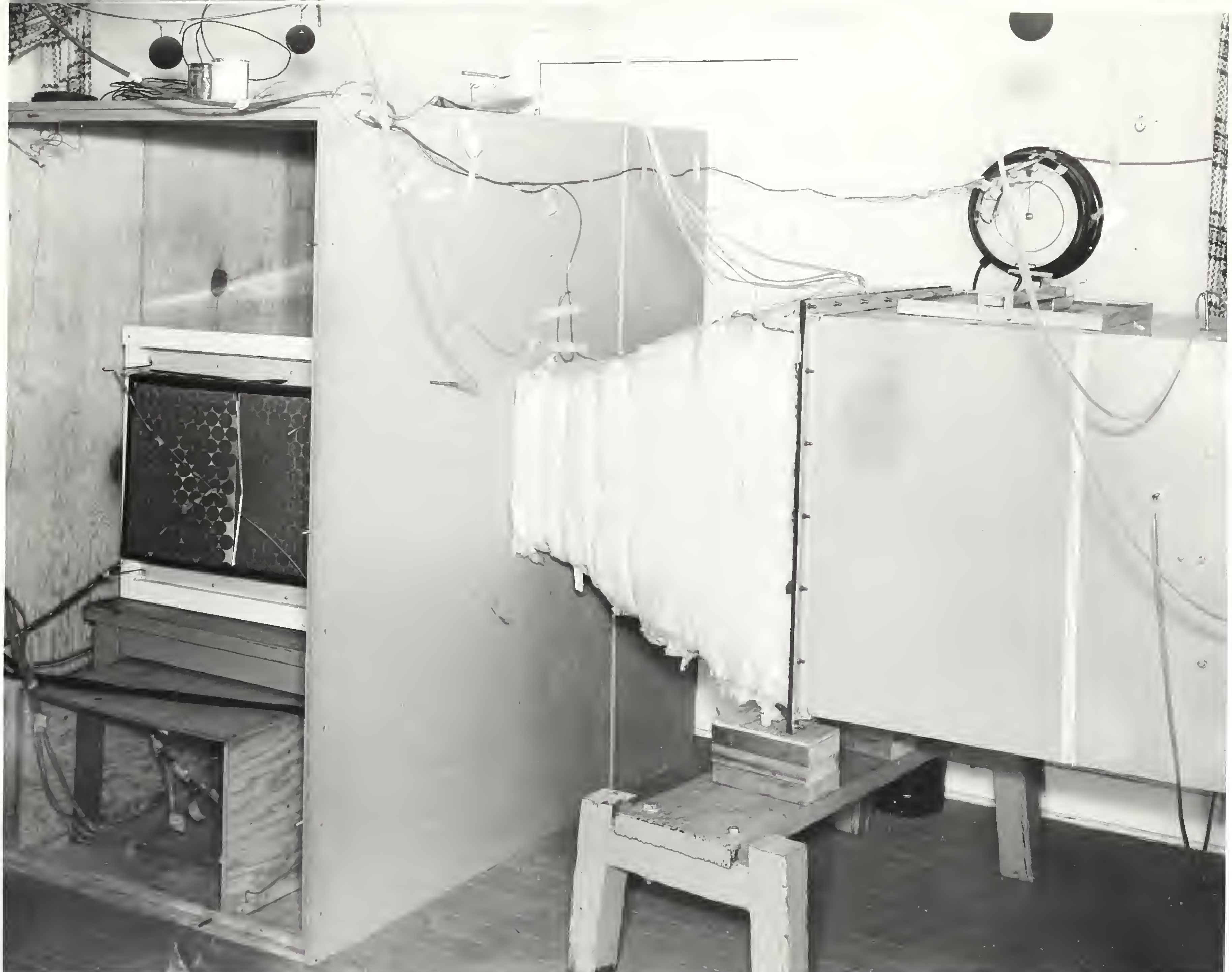

Figure 4

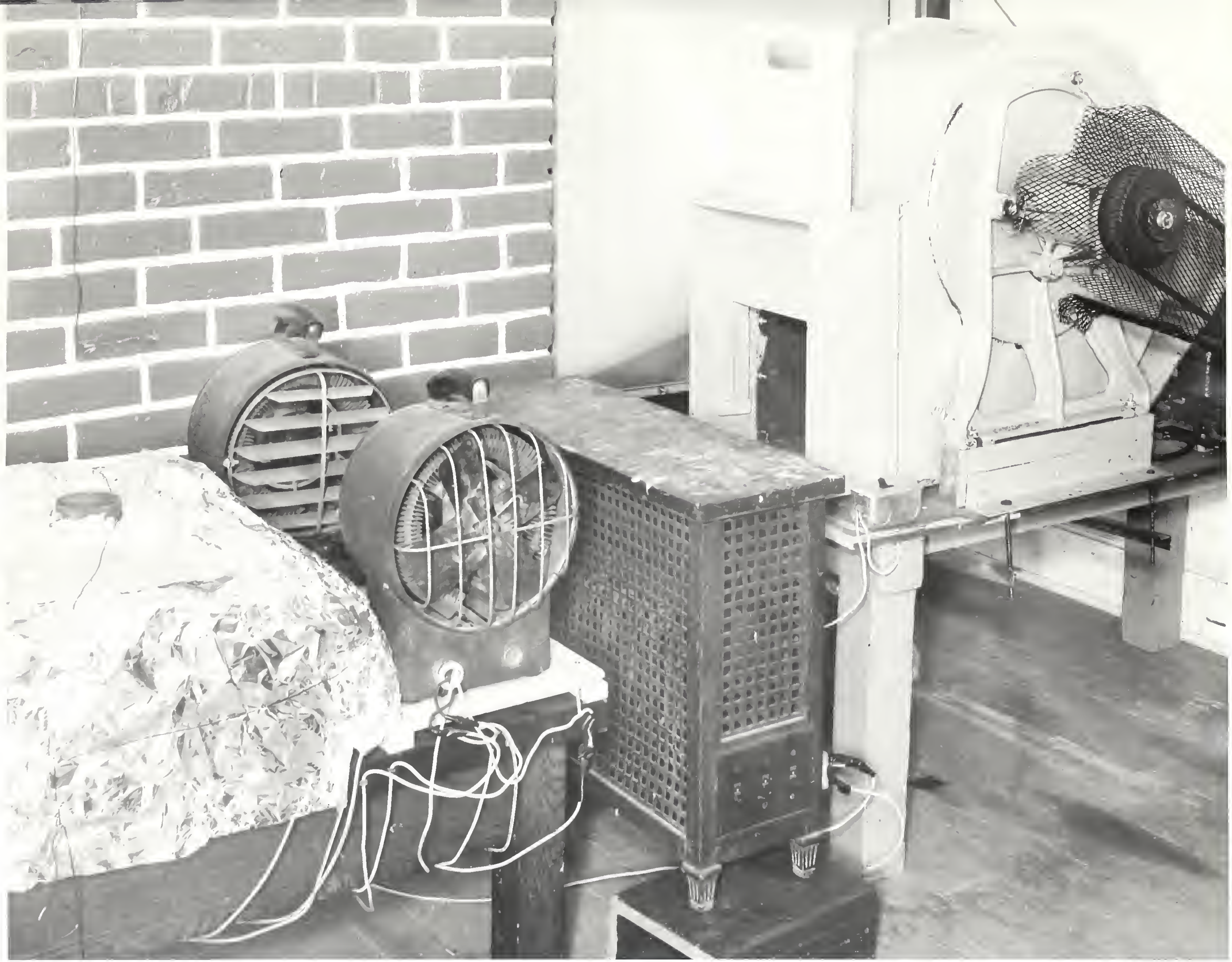

Figure 5

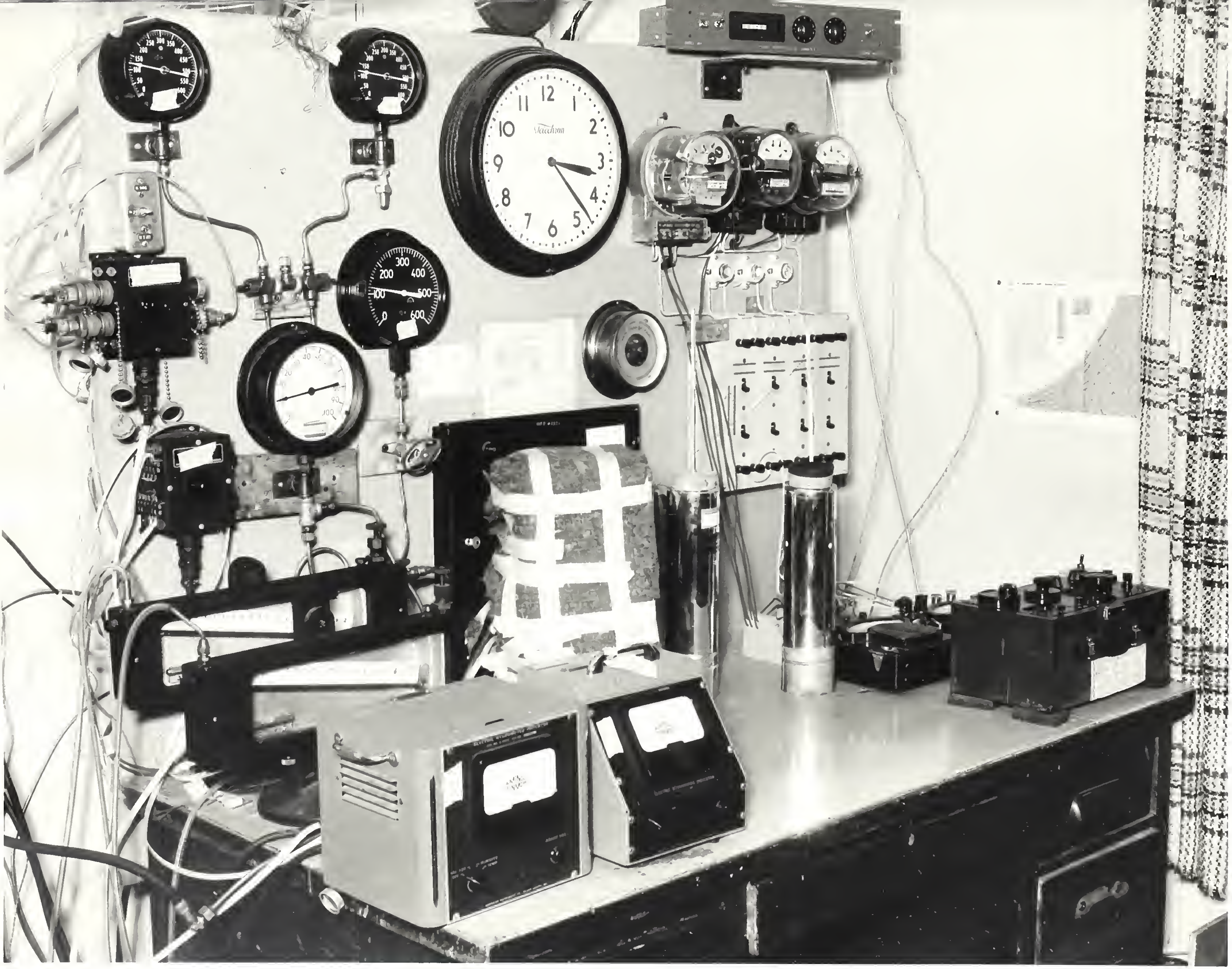

Figure 6

THE NATIONAL BUREAU OF STANDARDS

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Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

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Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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